INTRAFORMATIONAL PEBBLES IN THE RICHMOND GROUP, AT WINCHESTER, OHIO

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Ripple-marks, measuring two feet or more from crest to crest, occur at numerous horizons in the Ordovician rocks of Ohio, Indiana, and Kentucky, but are abundant especially in the middle parts of the Richmond group, where they characterize the upper part of the Waynesville formation and the lower part of the immediately overlying Liberty formation. Among the occurrences of ripple-marks discussed by Prosser, in his recently published paper on the "Ripple-Marks in Ohio Limestones,"[1] the following belong to the lower part of the Liberty formation: Elk Run, a little over a mile east of Winchester, Ohio (Figs. 1, 2); Cherry Fork, at Harshaville, 6 miles east-southeast of Winchester; and Treber Run, 5 miles southeast of Harshaville. The ripple-marks described by Joseph Moore and Allen D. Hole from a small western tributary of the Whitewater River, 5 miles southwest of Richmond, in Indiana, and those described by W. P. Shannon from the bed of Salt Creek, 3 miles west of Oldenburg, 38 miles southwest of Richmond, also occur in the lower part of the Liberty formation. At the Ridenour Mill, 5½ miles northwest of Oxford, Ohio, the ripple-marks described by Nelson W. Perry[2] occur both in the lower part of the Liberty and in the upper part of the underlying Waynesville formation. In fact, over a large part of Ohio and Indiana, ripple-marks are fully as abundant in the upper part of the Waynesville as in the lower part of the Liberty, and the list of localities might be multiplied almost indefinitely. Ripple-marks occur also near the top of the Brassfield formation at numerous localities in southern Ohio (Figs. 3, 4) and northern Kentucky, east of the Cincinnati axis.

[1] *Jour. Geol.*, XXIV, No. 5 (1916), pp. 456–57.

[2] *Am. Geol.*, IV (1889), 326–36.

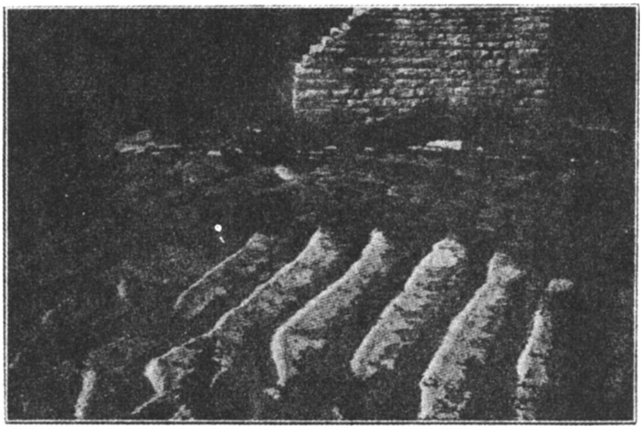

FIG. 1.—View of ripple-marked limestone in bed of Elk Run, looking northward toward abutment of road bridge. The appearance of strong contrast in the slope on opposite sides of the ripples is due to the dip of the rock toward the right causing the water to rise higher on the left side of the crests. In reality, the difference in slope on the two sides is small.

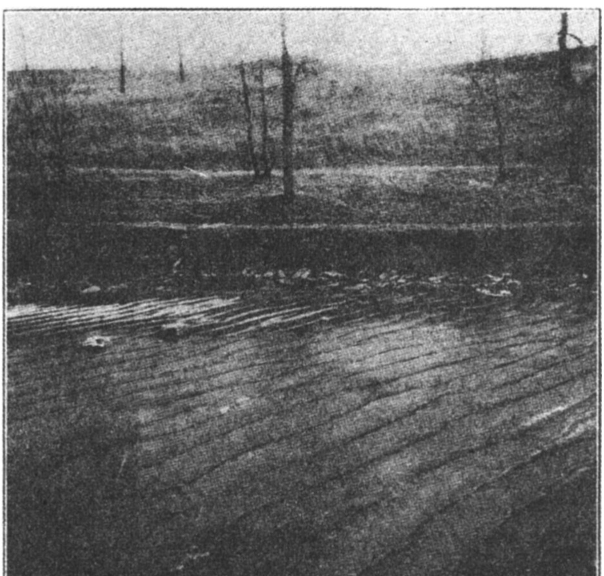

FIG. 2.—View at the same locality, looking northeast across the stream. See also Fig. 2, on p. 460 in *Journal of Geology*, XXIV, No. 5 (1916).

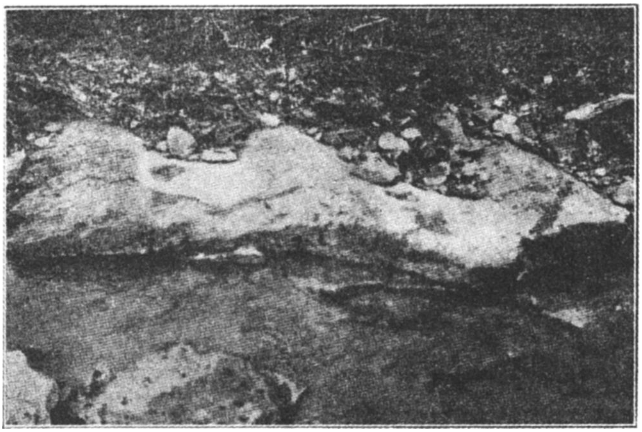

FIG. 3.—Ripple-marks on Brassfield limestone in Beasley Fork, a mile and a quarter south of West Union, Ohio. Note the small difference in slope on the two sides of the ripples.

FIG. 4.—Ripple-marks at the same locality and horizon on Beasley Fork

Occasionally pebbles occur in the ripple-marked layers of limestone. These pebbles usually are few in number and rarely are sufficiently abundant even to suggest the term conglomerate. They are more abundant at two horizons in the lower part of the Liberty formation at the locality on Elk Run, east of Winchester, Ohio, described by Prosser, than at any other localities known at present in the Ordovician of Ohio, Indiana, and Kentucky, and therefore this locality has been chosen to present some of the features characteristic of these pebbles. The pebbles are of two types.

1. In one type the rock is very fine-grained, as though originating from a calcareous mud, and is frequently marked by worm-burrows. There are also peculiar gouged-out markings, 3 or 4 mm. wide, 60–100 mm. long, often 20 mm. deep at the center, curving downward from the ends toward the center as though carved out by some narrow gouge. Markings of this kind frequently connect the two oblong or nearly circular terminals forming the peculiar dumb-bell fossil called *Arthraria*. There are also gouged-out markings only an inch in length (Fig. 6, pebble *C*). The surface of these pebbles often is very irregularly rounded, as though the rock had been soft at the time of formation of the pebbles. At one horizon these pebbles frequently support small colonies of the incrusting coral *Protarea richmondensis* (Fig. 5), 40–70 mm. in width. In fact, twenty pebbles supporting *Protarea richmondensis* were exposed along a narrow outcrop, a foot wide and scarcely 50 feet long, at the time of my last visit. Young specimens of *Streptelasma*, presumably *Streptelasma rusticum*, 10–15 mm. in length, occasionally occur, attached by their sides to the pebbles. Three pebbles supporting young specimens of *Streptelasma* occurred in the 50-foot length mentioned above. Incrusting growths of *Dermatostroma corrugata* and of various thinly incrusting bryozoans also occur occasionally. Since the incrusting growths follow the irregular curvature of the pebbles, it is evident that the latter is not due to subsequent erosion. In one specimen, thinly incrusting bryozoans and growths of *Stomatopora* occur on the lower side of the pebble, while thicker growths of *Protarea richmondensis* occur on the upper surface, showing that the pebble had been turned over at least once.

The fine-grained mud of which these pebbles are composed incloses but few fossils. In three pebbles *Lophospira bowdeni* was found, and one pebble contained a ventral valve of *Dinorthis subquadrata*, a characteristic fossil of the Liberty formation, unknown in the underlying Waynesville strata. In other words, there is no reason for believing that the rock of which the pebbles are composed is older than that of the formation in which the pebbles now occur. In fact, at several localities along the creek, the rock immediately underlying the pebble-bearing layer is sufficiently similar to the rock forming the pebbles to have given origin to the latter.

These fine-grained pebbles usually do not exceed 6 inches in length, 3 inches in width, and an inch in thickness, but specimens 12 inches long, 7 inches wide, and 2 inches thick are known, and one pebble 18 inches long, 11 inches wide, and 3 inches thick was observed.

2. The second type of pebbles usually consists of a fine-grained blue limestone, in which the grain is distinctly less fine than in the first type. The granular structure usually may be recognized without the assistance of a magnifier. Worm-burrows usually are absent, and no incrusting bryozoans or specimens of *Protarea* have been observed. The color of the rock is bluish gray, similar to that of the inclosing rock, and the outlines of the pebbles may be distinguished from the latter chiefly by the finer grain of the rock forming the pebbles, and usually also by differences in the stratification planes running through the rock. Such fossils as occur in these pebbles suggest the Liberty age of the rock from which the latter were derived, and the source of this rock could have been one of the underlying layers within this formation.

The pebbles of this second type usually are relatively thin and flat. The upper and lower surfaces usually are parallel, the lateral margins often being vertical or rounding only moderately into the upper and lower surfaces. In vertical cross-sections, therefore, the pebbles appear angular at the margins. Angularity frequently characterizes also the lateral outlines, as observed from above. In other words, the pebbles frequently appear broken off from thin layers of limestone, without much rounding. Some of

the pebbles are only 4 inches in length, and only a few exceed 12 inches in length, 7 inches in width, and 1 inch in thickness, but occasionally specimens much larger than this are seen. One

FIG. 5.—Pebble, of natural size, supporting two colonies of *Protarea richmondensis*. From layer D in the Elk Run section, east of Winchester, Ohio.

FIG. 6.—Limestone slab, of one-third natural size, supporting several pebbles; of these the one represented by Fig. 5 is located at *A*, but in an inverted position. From layer D in the Elk Run section, east of Winchester, Ohio.

pebble 38 inches long, 28 inches wide, and 2.5 inches thick was found.

The relative position of the pebble-bearing layers among the ripple-marked limestones along Elk Run may be seen from the following section. Ripple-marked layers occur here at various levels in a section at least 30 feet thick. Owing to the fact that the dip of the rocks is in the same direction as the flow of the stream, several layers disappear below the level of the stream at one point and reappear farther down the stream. This makes the unraveling of the section more or less difficult in places, but the following section, described in descending order, is as nearly correct as may be determined from the present condition of the exposures, which is unusually favorable for this locality.

SECTION ALONG ELK RUN, 1.5 MILES EAST OF WINCHESTER, OHIO

		Ft.	In.
Layer A.	Exposed about 600 feet south of railroad bridge; crest of ripples running N. 47° W. Pebbles few.		
Interval		5	
Layer B.	Crest of ripples running N. 40° W.		
Interval		3	9
Layer C.	Crest of ripples running N. and S.		
Interval			9
Layer D.	Crest of ripples running N. 40° W. This layer is not ripple-marked southeast of the home of Charles Bailey, but here numerous fine-grained pebbles, many supporting growths of *Protarea richmondensis*, occur (Figs. 5, 6).		
Interval		1	
Layer E.	Crest of ripples running from N. 30° W. to N. 25° W.		
Interval			9
Layer F.	Crest of ripples running N. 35° W.		
Interval		1	6
Layer G.	Crest of ripples varying from N. 3° W. to N. 15° W. at the small fall northeast of the home of Charles Bailey. This layer is exposed also immediately north of the road bridge, and between the road bridge and the railroad bridge. It is characterized by angular, flat pebbles, few in number, but sometimes of considerable length and width, considering the small thickness.		
Interval		6	

		Ft.	In.
Layer H.	Crest of ripples running N. 15° W.		
Interval	....	5	
Layer I.	Crest of ripples running N. and S., faintly defined. Near home of E. E. Jamison.		
Interval	....	5	
Layer J.	Poorly defined ripple-marks, at next house on west side of creek.		
Interval	....	1	
Layer K.	Crest of ripples running N. 70° E.		
Interval	....	1	
Layer L.	Crest of ripples running N. 50° E.		

The fine-grained pebbles first described, apparently consisting of a lime mud, supporting incrusting growths of *Protarea*, *Dermatostroma*, and various species of bryozoans, are specially characteristic of layer D. This layer is exposed at several localities along the creek, but the pebbles are common only southeast of the home of Charles Bailey, on the eastern side of the creek. Here the pebbles rest upon the top of the layer or are more or less imbedded in its upper part. This pebble-bearing layer is exposed also farther up stream, about 500 feet north of the road bridge. Here the pebbles vary from 2 to 4 inches in length, and from a quarter to half an inch in thickness. Farther up stream, immediately south of the road bridge, this layer is strongly ripple-marked, the crest of the ripples running N. 40° W. One pebble was noticed here 14 inches long, 7 inches wide, and half an inch thick. Farther north, where the pebbles are abundant, ripple-marks are absent.

The less fine-grained and more angular blue limestone pebbles, described last, occur in layer G. This layer is exposed between the railroad bridge and the road bridge, a short distance northward. The crests of the ripple-marks vary here (Figs. 1, 2) between N. 3° W. and N. 15° W. in direction, and on the average are about 30 inches apart. The following pebbles were noticed here, imbedded within the upper part of the ripple-marked layer, only the upper surface being exposed. In each case the length, width, and thickness of the pebble are given. One pebble, $4\times3\times0.5$ inch, lay in a trough and sloped gently toward the west. Another, $12\times7\times0.5$ inch, lay in a trough in a horizontal position. Two pebbles, $4\times4\times0.25$ inch, lay in a trough and sloped toward the east. Two pebbles,

4 inches in transverse diameter, lay in a trough in a horizontal position. One pebble, 8×5×0.5 inch, was imbedded on the eastern side of one of the crests, but in a horizontal position. Two pebbles, one on the eastern and one on the western side of the same crest, were in a horizontal position. The steeper side of the ripple-marks lies on the western side of the crests. The same layer is exposed immediately north of the road bridge, with layer D about 3 feet 3 inches farther up.

Layer G is exposed again at the small waterfall northeast of the home of Charles Bailey. The crests of the ripple-marks here run N. 3° W., the crests are about 28 inches apart, and the steeper slope is on the western side. Here the following pebbles were noticed, the dimensions being given in inches: one pebble, 10×7×1 inch, in a horizontal position, imbedded along the crest of one of the ripples; a pebble, 12×7×1 inch, in a horizontal position, buried under the western half of a crest; a pebble, 38×28×2.5 inches, in a horizontal position, imbedded so that its upper surface is on the same level as that of the surrounding rock. The moderately rounded margins are slightly overlapped by the surrounding rock; and the ripple-marks characterizing the latter are clearly defined as far as the margin of the pebble, but are absent, of course, on the surface of the latter.

Layer G is exposed also farther down the stream, northward. Here the crests of the ripples run N. 15° W., both sides of the ripple-marks sloping equally. One pebble, 6×4×1 inch, was imbedded up to its upper surface within the ripple-marked layer, and an incrusting bryozoan overlapped one margin of the pebble and the adjacent part of the surrounding rock, showing that enough time elapsed before the deposition of the overlying clay bed to admit of the growth of this bryozoan, the thickness of the latter being about 3 or 4 mm.

The pebbles in layer A were few in number. One pebble, 6×4×0.5 inch, consisted of fine-grained rock, resembling the worm-burrowed layer beneath the ripple-marked limestone. Farther north, nearer the railroad bridge, several additional pebbles, consisting of the same kind of rock, were found. The crests of the ripples run N. 47° W., they are 20–30 inches apart, the inter-

vening troughs are about 2.5 inches deep, and the steeper slope is on the western side.

All of the strata included within the 30-foot section here described belong to the Liberty formation. The lowest layer, L, contains the characteristic fossil *Dinorthis subquadrata*, and *Plectambonites sericea* is so abundant here that it suggests a horizon not far above the base of this formation. The abundance of typical *Strophomena planumbona* throughout the section suggests the lower half of the Liberty. *Strophomena vetusta*, associated with *Dinorthis subquadrata* and *Rhynchotrema capax*, is comparatively rare until the layers immediately overlying layer A are reached, but the general aspect of the rock here still is that of the Liberty formation.

Judging from exposures on Graces Run, a little over a mile west of Harshaville, the highest strata exposing ripple-marks occur at least as far up as within 88 feet of the base of the Brassfield limestone. Pebbles up to $6 \times 4 \times 0.5$ inch in dimension occur at a small fall half-way between this point and the mouth of Martins Run, half a mile southeastward. Several pebbles occur also in the wave-marked layers in the bed of Cherry Fork, immediately west of Harshaville.

The highest ripple-marked horizon along Elk Run, east of Winchester, appears to be about 80 feet below an exposure of Brassfield limestone seen along the railroad, west of the creek.

Pebbles up to $7 \times 4 \times 0.5$ inch in dimension occur also on Treber Run, about a quarter of a mile west of the mouth of the stream, a short distance west of the first crossing of the road following the stream. Here the pebbles occur in large, loose slabs of limestone containing a Liberty fauna, and evidently not transported far. The pebbles consist of small-grained blue limestone, similar to those occurring in layer G in the Elk Run section.

Perhaps the chief reason why the presence of pebbles in these ripple-marked strata has received so little attention is because they are so readily overlooked. By far the larger number of pebbles are horizontal in position, their stratification planes coinciding in direction with those of the inclosing rock. Especially is this true of the larger pebbles, while the smaller pebbles occasionally occur

at distinct angles with the inclosing rock. Moreover, the upper surface of the larger pebbles rarely projects distinctly above the surface of the inclosing rock, but more commonly is about at the same level as the latter. On careless examination, the pebbles appear merely as adhering remnants of the next overlying layer of rock. They are distinguished chiefly by the finer grain of the pebbles, frequently accompanied by a difference in color and by a difference in the character and location of the stratification planes.

There is no evidence that the larger pebbles, a foot or more in diameter, ever were turned over so as to present the lower instead of the upper surface of the original rock stratum. Perhaps this statement could be made with equal accuracy of any pebble 6 inches in width. The largest pebbles, so far found, which give evidence of having been overturned before being imbedded have a width of almost 3 inches, although the length may equal 6 inches. In one of these pebbles, obtained from layer D in Elk Run, a thin growth of *Ceramoporella ohioensis* on one edge of the pebble overlaps both the upper and the lower surface of the latter by fully an inch, and additional growths of the same species occur on the lower surface, the entire width of the pebble being $2\frac{3}{4}$ inches. The incrusting specimens of *Protarea* frequently occur on the upper surface of the pebbles, often several colonies on the same pebble, and these colonies frequently overlap the lateral edges, but never occur on the lower surface of the pebbles.

The size and the angularity of the larger pebbles suggest that they have not been transported very far. The absence of overturning of these larger pebbles also suggests only a short distance of transportation. The very irregular surface features of the very fine-grained pebbles, among which evidences of overturning are more frequent, suggest washed lumps of partly indurated calcareous mud rather than strongly eroded and frequently overturned rock.

Although rock similar to that forming the pebbles frequently occurs immediately below the layer in the upper surface of which the pebbles are imbedded, these ripple-marked layers frequently are continuous over such large areas, as determined from exposures along the lateral branches of streams, as to make the origin of the pebbles from underlying strata more or less doubtful. Especially

is this true in the case of the larger pebbles, which apparently have been transported only short distances.

Moreover, there is no evidence of strong unconformities anywhere in the Richmond series of rocks. At no point has a layer of rock been found to overlap the lateral margins of any of the layers for even a vertical distance of 2 feet. Hence an origin from anything like a cliff or coast or beach seems questionable. At least there is no evidence of the presence of any cliff, coast, or beach sufficiently close to the area in question to have furnished the material for the pebbles.

There was a tendency formerly to regard the presence of ripple-marks as evidence of shallow-water conditions and as suggesting the proximity of shore lines. This found expression in a paper by Joseph F. James on the "Evidences of Beaches in the Cincinnati Group."[1] Here the ripple-marks in the upper part of the Cynthiana formation, at Ludlow and West Covington, Kentucky, opposite Cincinnati, and another set of ripple-marks about 300 feet above low-water mark in the Ohio River, presumably in the upper part of the Eden formation, were interpreted as evidences of the proximity of beaches. As further evidence of shallow-water conditions during the deposition of various parts of the Cincinnati group, the presence of raindrop impressions near the top of the Cincinnati group was cited, but the exact location of the rock bearing these raindrop impressions is not given.

The impression that at least a part of the rocks of the Cincinnati group were deposited in very shallow waters finds expression also in a paper by Nelson W. Perry on "The Cincinnati Rocks; What Has Been Their Physical History?"[2] Here raindrop impressions are cited from the vicinity of Smiley's Dam, 3½ miles southeast of Oxford, but 5 miles distant when approached by the road. The dam is located on Fourmile Creek. The lowest strata exposed belong to the Mount Auburn division of the Maysville formation, and a mile westward the *Dinorthis carleyi* horizon near the middle of the Arnheim bed is exposed at an elevation about 50 feet higher. Careful search by the present writer failed to locate

[1] *Science*, V (1885), 231.

[2] *Am. Geol.*, IV, No. 6 (1889), pp. 326–36.

the presence of raindrop impressions or of any other evidences suggesting deposition under shallow-water conditions.

Perry next calls attention to the exposures at the Ridenour Mill, on Little Fourmile Creek, about 7 miles north-northwest of Oxford, where numerous layers in the upper part of the Waynesville and lower part of the Liberty divisions of the Richmond group are ripple-marked.

Next, Perry cites the presence of mud-cracks from a locality near Moores Hill in Dearborn County, in Indiana, presumably from the Waynesville division of the Richmond group. And, finally, he alludes to the well-known ripple-marks in the upper part of the Cynthiana formation, at Ludlow, Kentucky.

Now, whatever may be the opinion concerning the value of ripple-marks as evidence of shallow-water conditions, there can be no difference of opinion as to the evidence presented by raindrop impressions and mud-cracks. However, the presence of raindrop impressions and of mud-cracks must be fully proved. This the present writer has been unable to do.

Specimens formerly interpreted by him as exhibiting raindrop impressions he now regards as ripple-marked, irregular ripples of short amplitude crossing at various angles, leaving intermediate more or less circular hollows. If anyone has clear evidence of the presence of raindrop impressions in Cincinnatian strata, this evidence should be published, accompanied by clear illustrations.

As regards the presence of mud-cracks, the present writer has seen many occurrences of structures suggesting mud-cracks, but has come to regard their origin from exposure of mud-flats to aerial conditions as extremely doubtful.

When mud exposed to the drying effects of the open air cracks, it not only tends to pull apart at the cracks, but the upper, more rapidly drying part tends to pull away from the part beneath. Frequently the cracked surface becomes sufficiently hardened to remain more or less intact when the next tide proceeds to cover it. This causes the subsequently deposited material to settle in part in the cracks, and frequently the part filling the cracks is sufficiently different to be readily distinguished from the original mud deposit.

In the case of sea deposits, the material filling mud-cracks might include coarser-grained deposits or organic material, either entire or fragmental. Now, it is the very frequency of the supposed mud-cracks with the absence of the concurrent phenomena here indicated which throws doubt on their interpretation. In such "mud-cracks" as have been observed hitherto, the material filling the cracks is essentially the same material as that forming the lateral walls of the crack, and no fossil or fragmental material has ever been found in a position suggesting that it had been dropped into the crack, or had been washed into it.

On the contrary, in many cases it has appeared possible that the cracking could have occurred subsequent to the deposition of the overlying strata, in fact long subsequent to the latter, and may not be due to the drying effects of the air along a seashore, but to shrinkage of strata deposited in much deeper waters. Mud deposits in quiet waters have been known to crack without exposure to the air, although the observed cracks have always been of too small magnitude to suggest mud-cracks. Shrinkage, however, may have occurred also long subsequent to the deposition of the overlying strata, during a period of elevation of the entire mass of marine deposits. The gradual filling of the cracks might have been accomplished by slowly circulating waters while the shrinking material still was comparatively soft. While the method of filling of these cracks may vary in different cases, the possibility of their origin from shrinkage long after the deposition of the strata in which they occur should be considered. If anyone has any evidence of the presence of mud-cracks in Cincinnatian rocks which unquestionably are due to elevation of mud flats above water-level before the deposition of the immediately overlying strata, this evidence should be published in detail.

Until the presence of raindrop impressions and of mud-cracks due to exposure of mud-flats to the open air before the deposition of the overlying strata has been proved unequivocally, it is not so certain that ripple-marks indicate shallow-water conditions. They may have been formed a considerable distance below sea-level, at least sufficiently far not to necessitate the immediate presence of a shore line.

Formerly, pebbles were regarded as unequivocal evidences of the proximity of a shore line, but even these may be formed below water-level. This is true especially of the pebbles found in the Ordovician strata of Ohio, Indiana, and Kentucky, since these usually occur only in ripple-marked layers, or in lateral extensions of these layers. The same causes which gave rise to the ripples may have given rise to the pebbles.

These causes apparently include a more or less rapid flow of water. The ripple-marked layers usually consist of more or less fragmental detrital or organic material, frequently in much greater quantity and of coarser grain than in the immediately overlying and underlying layers, as though freed from the accompanying calcareous and argillaceous muds by repeated rewashings of the materials constituting the ripple-marked layers. These muds either were washed to more distant areas or were, in part, held in suspension in the overlying waters for a short time. The ripple-marked layers frequently show evidences of cross-bedding, especially immediately beneath the crests of the ripples, thus also suggesting current action. The larger pebbles, a foot or more in diameter and only an inch or two in thickness, may easily have been formed by currents dissecting a more or less fine-grained stratum, and leaving remnants of the latter more or less imbedded in the current-washed material farther on. In limestone layers not exceeding four inches in thickness, even directly beneath the crests of the ripples, the larger pebbles scarcely could incline very much. The source of the pebbles readily could have been some formerly existent layer located less than a foot above the present level of the pebble. The finer muds of the intervening section could have been washed away, and the coarser material retained to form the major part of the ripple-marked layer, in the upper surface of which the limestone pebbles are imbedded.

Especial attention should be called to the fact that, even where the ripple-marked layers are most abundant, many of the intermediate limestone layers may show no trace of ripples. Hence, the frequent absence of ripple-marks needs explanation fully as much as their locally more or less frequent presence.

One of the causes giving rise to widespread current-action may have been violent and widespread storms. Considering the fact that the Cincinnatian strata were deposited in epicontinental seas, storms easily, at times, might have blown vast quantities of water over those parts usually covered only by shallow waters. Such storms occasionally are experienced on the Gulf coast, and along the coast of the southern Atlantic states. The ebb flow of these accumulated waters, after the storm, might easily give rise to widespread ripple-marking of the last deposited strata, even at a considerable distance from actual shore lines. Such an origin of currents would predicate wide areas of gradually shallowing seas over which the surface waters blown before the wind would tend to accumulate. Currents due to such causes might be expected more readily in the comparatively shallow waters of epicontinental seas than along the more abrupt shores of the deeper oceanic basins.

The presence of numerous well-preserved colonies of *Protarea* and of delicate growths of *Stomatopora* and other bryozoans on the upper surface of the pebbles at the Elk Run locality, east of Winchester, Ohio, is indicative of submerged conditions at least immediately after the formation of the pebbles. In a similar manner, the long crinoid columns found on the surface of the ripple-marked layers of lower Trenton limestone, at Hull, in Canada,[1] indicate that fairly deep waters were present immediately after the formation of the ripple-marks, and may have been present even during their formation.

Ripple-marks comparable in dimension with those characteristic of the Ordovician limestones of Ohio, Indiana, and Kentucky are not unknown along our present shores. They occur where waters accumulating in extensive salt marshes or in estuaries during high tide find a ready outflow to the sea during ebb conditions. In these cases the steeper slopes of the ripple-marks are directed away from the shallower waters.

It is remarkable, however, in the case of the ripple-marks on the Ordovician limestones of the areas here under discussion, how

[1] Kindle, *Jour. Geol.*, XXII (1914), 712.

slightly the slopes on the two sides of the crests of the latter differ in most cases. Frequently it is difficult to determine a difference in slope at all, and rarely is this difference strongly defined, as in the case of the strong ripples found after ebb tide along our present coasts.

Eventually it may be possible to accumulate sufficient evidence to determine with considerable certainty the conditions under which many of the strata of ancient days were deposited. To many the evidence appears to be already at hand. To others a revision of the evidence may appear necessary. To the writer it appears desirable that those who have indubitable evidence of land conditions during the deposition of Ordovician strata in the states of the Ohio Valley should publish the same. This is true especially in case of raindrop impressions and of mud-cracks, which are favorite evidences locally of shore and land conditions during Ordovician times.